DOCUMENT-IDENTIFIER: US 6069433 A
TITLE: Packaged strain actuator

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6069433

BSPR:
One approach to incorporating piezoelectric elements, such as a thin piezoelectric plate, a cylinder or a stack of discs or annuli, into a controllable structure has been described in U.S. Pat. No. 4,849,668 of Javier de Luis and Edward F. Crawley. This technique involves meticulous hand-assembly of various elements into an integral structure in which the piezoceramic elements are insulated and contained within the structure of a laminated composite body which serves as a strong support. The support reduces problems of electrode cracking, and, at least as set forth in that patent, may be implemented in a way calculated to optimize structural strength with mechanical actuation efficiency. Furthermore, for cylinders or stacked annuli the natural internal passage of these off-the-shelf piezo forms simplifies, to some extent, the otherwise difficult task of installing wiring. Nonetheless, design is not simple, and fabrication remains time-consuming and

subject to
numerous failure modes during assembly and operation.

BSPR:
In accordance with a further aspect of the invention, circuit elements are
formed in, or with, the modular package to filter, shunt, or process the signal
produced by the PZT elements, to sense the mechanical environment, or even to
locally perform switching or power amplification for driving the actuation
elements. The actuator package may be formed with pre-shaped PZT elements,
such as half-cylinders, into modular surface-mount shells suitable for
attaching about a pipe, rod or shaft.

DEPR:
In general, the invention includes novel forms of actuators and methods of
making such actuators, where "actuator" is understood to mean a complete and
mechanically useful device which, when powered, couples force, motion or the
like to an object or structure. In its broad form, the making of an actuator
involves "packaging" a raw electro-active element to make it mechanically
useful. By way of example, raw electro-active piezoelectric materials or
"elements" are commonly available in a variety of semi-processed bulk material
forms, including raw piezoelectric material in basic shapes, such as sheets,
rings, washers, cylinders and plates, as well as more complex or

composite
forms, such as stacks, or hybrid forms that include a bulk material with a
mechanical element, such as a lever. These materials or raw elements may have
metal coated on one or more surfaces to act as electrical contacts, or may be
non-metallized. In the discussion below, piezoelectric materials shall be
discussed by way of example, and all these forms of raw materials shall be
referred to as "elements", "materials", or "electro-active elements". As noted
above, the invention further includes structures or devices made by these
methods and operating as transducers to sense, rather than actuate, a strain,
vibration, position or other physical characteristic, so that where applicable
below, the term "actuator" may include sensing transducers.

DEPR:
Embodiments of the invention employ these stiff electrically-actuated materials
in thin sheets--discs, annuli, plates and cylinders or shells--that are below
several millimeters in thickness, and illustratively about one fifth to one
quarter millimeter thick. Advantageously, this thin dimension allows the
achievement of high electric field strengths across a distance comparable to
the thickness dimension of the plate at a relatively low overall potential
difference, so that full scale piezoelectric actuation may be obtained with

driving voltages of ten to fifty volts, or less. Such a thin dimension also
allows the element to be attached to an object without greatly changing the
structural or physical response characteristics of the object. However, in the
prior art, such thin elements are fragile, and may break due to irregular
stresses when handled, assembled or cured. The impact from falling even a few
centimeters may fracture a piezoceramic plate, and only extremely small bending
deflections are tolerated before breaking.